NOAA Technical Memorandum
NOS MEMD 10

MONITORING OF FISHES AND INVERTEBRATES AT TIJUANA ESTUARY

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Washington, D.C.
August 1987

UNITED STATES DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Ocean Service

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National Ocean Service Series

Marine and Estuarine Management Division

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REPORT TO
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

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OFFICE OF OCEAN AND COASTAL RESOURCE MANAGEMENT
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This work is the result of research sponsored by the U.S.
Department of Commerce, National Oceanic and Atmospheric
Administration, National Ocean Service, Office of Ocean and
Coastal Resource Management, Marine and Estuarine Management Division
Under Contract Number NA-86-AA-D-CZ016

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Abstract

Fishes and benthic invertebrates responded differently to the impacts of elevated water salinities and temperatures due to closure of the estuary mouth; sedimentation as the result of dune sand deposition in estuarine channels; and, dredging to remove those sediments. Increased salinities resulted in the mortality of all benthic invertebrates except spionid worms. California halibut (Paralichthys californicus), Diamond turbot (Hypsopsetta guttulata), and Pacific staghorn sculpin (Leptocottus armatus) were not encountered at salinities higher than 50ppt, while Longjaw mudsucker (Gillichthys mirabilis) survived salinities as high as 100ppt but showed a lag response to increased salinities with populations declining in 1986-87. Benthic invertebrates demonstrated an immediate response to sedimentation while fish response was unclear. The dominant bivalves were eliminated and levels of polychaete worms drastically reduced by such events. While fish diversity and density were lower following sedimentation events, it could not be determined whether this response was due to avoidance of the area or mortality. Dredging to remove sediments resulted in the coincidental removal and mortality of benthic invertebrates.

Populations of both fish and invertebrates were dominated by small size classes, suggesting recruitment from oceanic sources. Due to the skewed distribution of size classes, the system is not stable in terms of population biology, and is susceptible to further physical fluctuations. It is recommended that such fluctuations be avoided by maintenance of tidal flushing and increasing tidal prism, despite the initial impacts to the channel biota.

Introduction

Tijuana Estuary, designated a National Estuarine Research Reserve by NOAA OCRM in 1982, is a small coastal wetland containing approximately 60ha of channels at high tide and 200ha of associated salt marsh (McIllwee 1970). A narrow barrier dune separates the main channels of the estuary from the Pacific Ocean (Figure 1). In January 1983, concurrent high tides and heavy surf washed dune sand into the main estuary channel, substantially reducing the tidal prism and ultimately causing the closure of the estuary mouth to tidal flushing. Closure occurred in early April, 1984, and tidal flushing was reinstated in December 1984. During this period precipitation was near zero and channel salinities rose to over 100ppt, eliminating the marine dominated channel biota.

The purpose of this study was to assess the effects of mouth closure and sedimentation on the system and monitor population dynamics of fishes and invertebrates following the reinstatement of tidal flushing and dredging to remove sediments. Adult and juvenile fishes, ichthyoplankton, and benthic invertebrates were monitored quarterly at 3-5 sites, depending upon season (Figure 1). In addition, the examination of summer zooplankton populations, extensive monitoring of bivalve populations, analysis of sampling efficiency, and gut analysis of juvenile halibut were conducted. In January 1, 1987, high tides again washed dune sand into the estuarine channels providing a natural experiment on the short-term effects of sedimentation on channel organisms.

Methods

Sampling Stations

Sampling sites were chosen on the basis of channel morphometry, a multi-factor parameter that describes channel depth, substrate composition, position relative to the mouth of the estuary, and bank slope. Station E1 was located in the main north-south channel of the estuary (Figure 1). The width and depth at this site varied from 13m to 14m and from .5m to .75m, respectively, depending upon tidal height. The eastern bank was sharply eroded while the western bank was gradual and depositional. Substrate was composed primarily of sand with some mud. Station E2 was located in a dredged channel situated east-west and connecting the inland lagoon with the main north-south channel. This site was 12m wide and depth varied from .3m to 1m. Banks were sharply eroded and substrate consisted of clay and shell fragments. Site E3 was a channel near the mouth of the estuary approximately 10m wide and .3m to .5m deep. The banks were gently sloped and substrate was sand/mud. Site E4 was a tidal creek corresponding to Net Creek of Nordby (1982). The width at E4 was 2m while depth varied from .5m to 1m. Banks sloped abruptly and substrate was fine mud. E5, another tidal creek, was sampled one time only in fall 1986 when the water level in E4 was too low to sample. This creek was 2m wide and 1m deep with gently sloping banks and fine mud substrate. Tidal creek habitats were intertidal, draining completely on lower tides. Thus, stressful conditions limited benthic invertebrate populations to various gastropods and polychaetes.

It was originally proposed that riverine channels, gravel pit ponds and intertidal ponds be sampled as well as main channels and tidal creeks. However, after the initial sampling period, these sites were omitted due to lack of useful information. For example, gravel pit ponds yielded only one (non-native) fish species (Mosquitofish, Gambusia affinis) while riverine channels proved too shallow to seine. Thus sampling stations were concentrated in the main channels and tidal creeks of the estuary.

Adult and Juvenile Fishes

Adult and juvenile fishes were collected using a 3mm mesh bag seine and two 3mm mesh blocking nets. The blocking nets were deployed at slack low tide to block a section of channel and contain fishes within that area. Repeated seines were hauled through the area until the number of fish captured per seine approached zero. The blocking nets were then closed by sweeping in toward the center of the blocked area. Sampling efficiency was tested by using the catch per unit effort method, where the number of fish caught is plotted against prior cumulative catch. This method compares the estimated total number of fish within the blocked portion of the channel with the actual number caught. In addition, the species composition of fishes captured in each repeated seine was compared to demonstrate the species selectivity of the sampling gear.

Ichthyoplankton

Fish eggs and larvae were collected at stations E1, E2, and E3 using three 30-cm diameter plankton nets of 505 micron mesh (Nitex nylon screen) with center mounted flow meters to estimate the volume sampled. Nets were deployed on the flood tide, 1.5 hour prior to high slack tide, and on the ebb tide 1 hour after high slack tide. Sampling was conducted for one hour, after which nets were removed, cleaned, and samples preserved in 3% formalin buffered with seawater.

It was proposed that ichthyoplankton be collected on both flood and ebb tides on each sampling date to determine the role of tidal transportation as the primary mechanism controlling ichthyoplankton distribution within the estuary, as hypothesized by Nordby (1982). However, due to reduced tidal circulation as a result of channel sedimentation, tidal cycles were unpredictable and often disrupted. Thus, only one tide, either ebb or flood, was usually sampled on a given date.

Benthic Invertebrates

Benthic infaunal invertebrates were sampled using a 15cm diameter "clam gun" as a coring device. This device was pressed into the substrate to a depth of 20cm and the core of sediment screened through a 1mm mesh sieve. All large animals were identified in the field and released. Smaller, unidentified organisms were fixed in 3% formalin buffered with seawater and taken to the laboratory for examination.

Invertebrates were sampled using two approaches: cores were taken in the areas blocked for adult and juvenile fish collection and concentrated sampling was conducted in areas where fishes were not sampled (Figure 1).

Zooplankton

Although not originally proposed for the monitoring program, the summer zooplankton populations within the main channels of Tijuana Estuary were examined by M. Hellberg, SDSU-U.C. Davis joint doctoral student. Collections were taken simultaneously with ichthyoplankton samples.

Results and Discussion

Adult and Juvenile Fishes

A total of 20 species of fish from 14 families was collected (Table 1). Dominant species include Topsmelt (Atherinops affinis), Arrow goby (Clevelandia ios), Pacific staghorn sculpin (Leptocottus armatus), and California killifish (Fundulus parvipinnis), all of which are generally regarded as resident estuarine species.

On a seasonal scale, species diversity was highest in spring and summer when 13 and 14 species, respectively, were collected and lowest in fall and winter when 9 species were taken during each sampling period (Figure 2).

Spatially, diversity was highest at station E1 (15 species) followed by E2 (14 species) and E3 (10 species) (Figure 3). Tidal creeks contained the lowest number of species with the combined total of 4 species at sites E4 and E5.

Densities of the dominant species were variable but some general patterns are evident (Table 1). Topsmelt were collected in high densities at all sites except E5, which was sampled on one date only (11/25/86) when tidal levels at site E4 were too low to allow seining. This is a highly mobile species that forms schools and utilizes the entire water column. Thus, it is difficult to correlate physical variables such as substrate and water chemistry with the distribution and abundance of this species.

The distribution and abundance of the other dominant species appear to be related to substrate type and other characteristics of channel morphometry - water depth, tidal velocity, and distance to the mouth of the estuary - and with the availability of food. Arrow goby densities were always highest at E3, the station closest to the mouth of the estuary. The channel at this site is shallow, with low tidal velocity and a sand/mud substrate. These physical characteristics make E3 a site conducive to burrow construction and maintenance by goby species (Brothers 1975). Arrow gobies greater than 14mm are benthic carnivores and feed primarily on cyclopoids, ostracods, nematodes, oligochaetes and harpacticoids (MacDonald 1975). The distribution and abundance of benthic invertebrates and zooplankton in Tijuana Estuary are presented in later sections of this report. However, sites E3 and E4, which contained the highest densities of Arrow gobies, contained abundant zooplankton and benthic worms. The association of Arrow gobies with commensal organisms such as Ghost shrimp (Callianassa californiensis) is well documented (Brothers 1975). Ghost shrimp burrows were abundant at both sites.

The high densities of gobies encountered at station E3 may help to explain the high numbers of gobiid larvae collected in plankton tows from nearshore waters adjacent to Tijuana Estuary in 1980-81 (Nordby 1982). A spawning event near the mouth would result in the tidal translocation of larvae to the nearshore habitat.

Pacific staghorn sculpin, which were abundant only during the spring and summer, occurred primarily in sandy substrate (E1) and sandy/mud (E3), although numerous small individuals were collected from E2 during March, 1987. This species feeds mainly on decapod crustaceans such as Ghost shrimp and Yellow shorecrab (Hemigrapsus oregonensis) (Tasto 1975). Ghost shrimp were abundant at both E1 and E3, while Yellow shorecrabs were common throughout the estuary.

Topsmelt greater than 34mm feed primarily on green algae, such as Enteromorpha sp. (Allen 1980). These algae are most abundant in Tijuana Estuary in late winter-early spring (Rudnicki 1986)and occur in greatest abundance in low tidal velocity channels. All of the sites sampled in this study supported periodic blooms of these algae.

The Longjaw mudsucker (Gillichthys mirabilis) is considered a resident estuarine species that preys upon and inhabits the burrows of larger crab species, such as the Yellow shorecrab. Despite the abundance of prey organisms, populations of Longjaw mudsuckers were very low at Tijuana Estuary during this study, relative to populations prior to and during closure to tidal flushing. Prior to closure, Longjaw mudsuckers were abundant in the tidal creeks of the estuary (Nordby, pers. obs.). Although comparable data from seining operations are not available, Longjaw mudsuckers were taken using minnow traps in 1979-80 (Nordby, unpub. data). Indirect evidence of the abundance of this species in the system prior to 1984 is demonstrated in the ichthyoplankton collections of Nordby (1982). Longjaws comprised 29% of the total larvae collected in main channels (3,878) and 79% (684) of those collected from a tidal creek using a channel net method (Nordby 1982).

During closure, an SDSU Estuarine Ecology class sampled seven sites within Tijuana Estuary. Longjaw mudsuckers were present at 2 main channel sites, corresponding roughly to E1, and in the east-west channel corresponding to E2. Channel salinities at this time were about 60 ppt. Although not numerous (Longjaws accounted for about 4% of the catch, or 22 of 575 fishes), they were widespread and relatively large, ranging from 77mm to 113mm. Thus, adults of this species can tolerate salinities of 60ppt. Whether or not they can spawn under such conditions is unknown. Salinities then rose to around 100ppt before reintroduction of tidal flushing.

In the current study, Longjaws were collected at only two sites on two dates (Table 1). Thirty-nine individuals were collected from E2 in August, while 2 individuals were taken from E3 in March. This low relative abundance suggests a lag effect of increased salinity. Although adults are present in the system, population levels are apparently so low that recovery will take several spawning seasons. The data from ichthyoplankton collections (see next section) demonstrate the low recruitment potential of this species in 1986-87.

Additional support for the salinity-induced population decline is provided by the results of a similar monitoring program at Los Penasquitos Lagoon (ERA 1987), an occasionally flushed lagoon approximately 40 miles north of Tijuana Estuary, and from spring 1987 sampling conducted at Bahia de San Quintin, a relatively pristine wetland located approximately 150 miles south of Tijuana Estuary in Baja, Mexico (Nordby unpub. data). Although Los Penasquitos Lagoon was closed to tidal flushing for much of 1986-87, Longjaw mudsuckers were the third most abundant species taken in this system, comprising 4.1% of the total catch, or 170 individuals. Although methods and net meshes were not comparable, a pattern of salinity and abundance can be demonstrated. Salinities during this period did not rise above 50ppt (range = 0ppt to 50ppt). At Bahia de San Quintin, two tidal creeks were sampled for fishes using the same methods as the present study. Longjaw mudsuckers comprised 43% (40) of the total caught at creek 1, and comprised 90% (72) of the total at creek 2. Salinities were 45ppt and 50ppt, respectively. Thus, populations can tolerate relatively high salinities but not extreme salinities such as 100ppt.

Other species showed similar responses to salinity. Samples collected at Tijuana Estuary during closure conditions lacked the common Staghorn sculpin, California halibut (Paralichthys californicus) and Diamond turbot (Hypsopsetta guttulata). These species were present in tidal creek 1 at Bahia de San Quintin where salinity was 45ppt, but were absent from tidal creek 2 where salinity was 50ppt. Thus, salinities greater than 50ppt appear to exceed the tolerance of several estuarine species.

Physical conditions during the present study were relatively stable (Table 2) with salinities ranging from 32ppt to 38ppt, temperature from 15 to 29C, and dissolved oxygen from 2ppm to saturated levels. There was little correlation between physical factors and fish distribution and abundance (Table 1). Tidal flushing was maintained throughout the 1986-87 sampling year, although at reduced levels due to sedimentation.

Test of Sampling Efficiency

In order to estimate population size and determine how many fish within the blocked area of the channel were actually captured, the following exercise was conducted at site E2 on March 10, 1987, and again on March 11, 1987: Repeated seines were drawn through the blocked area until the number of fish caught approached zero. Then, the two blocking nets were "closed" by pulling each toward the center of the blocked area. The total number of fish within the blocked area was calculated using the catch per unit effort method where the number caught is plotted against the prior cumulative catch (Figures 4a and 4b). The selectivity of the gear for various species was examined by plotting number caught in each repeated seine (Figures 5a and 5b).

As demonstrated by the catch per unit effort, five repeated seines and the two closing nets are necessary to adequately sample the fishes in the blocked channel. The sampling gear and the "catchability" of each species is similar in both cases. On March 10, 96% of the Topsmelt were taken in the first tow while on March 11, 69% of this species were captured in the first tow. Benthic fishes such as the dominant Arrow gobies comprised relatively few of the initial seine but were taken in increasingly higher numbers on the second and third tows before declining.

The two consecutive sampling dates also allow for a comparison of daily variation in the fish communities. This comparison was made because the high degree of daily and weekly variation in some systems renders seasonal comparisons meaningless. A similar test was conducted at site E1 on November 25 and November 26, 1986. Species composition was very similar at both sites for each comparison (Tables 3a and 3b). These results suggest that comparisons based on seasonal sampling are valid.

Size Frequency Analysis

Size frequency data for selected species (Figures 6-8) are included to show changes in various populations through time. Topsmelt collected from stations E1 and E2 demonstrated similar temporal patterns. Collections in spring were composed of two distinct size classes dominated numerically by smaller (<40mm) fish with fewer large (>100mm) individuals. These appear to represent the year 1 recruits and spawning adults, respectively. Summer collections were typified by larger, yet fewer, young of the year (around 50mm in length) and an absence of adults. While less clear at station E1, the collections from E2 in the fall show a bimodal distribution with the majority of those collected falling into the 100mm size with a second peak around 150 mm. These may be interpreted as the maturing year 1 recruits and adults, respectively. By winter 1987, Topsmelt collected at E2 were clustered around the 25-34mm size class, suggesting new recruits for that year. No Topsmelt were collected at E1 in the winter.

Size frequency analysis of California halibut (Paralichthys californicus) collected from station E2 shows developmental patterns for that species (Figure 4). Spring collections consisted of numerous small individuals, again indicating young of the year. Summer and fall collections were composed of progressively fewer, larger individuals, suggesting maturation of the year 1 class. Winter collections were dominated by few small individuals, the majority of which were from 10mm to 29mm. These represent the new year 1 age class. The smallest California halibut collected in this study was 9mm, taken at E2 in June 1986; the largest specimen was 430mm taken at station E1 in November.

Gut Analysis of Juvenile Halibut

California halibut (Paralichthys californicus) are one of the few commercially important species that inhabit southern California estuaries and lagoons. This species spawns offshore and uses these wetlands as a nursery ground. While the present study examines halibut distribution in Tijuana Estuary in relation to substrate, analysis of food items for different size juveniles was not proposed. Such an analysis was conducted on 20 juvenile halibut that died during sampling procedures. The results (Table 4) show a distinct pattern in food prey items taken by different size juveniles, despite the small sample size. Halibut larger than 70mm fed primarily on gobies and juvenile topsmelt, those between 70mm and 46mm ate mostly gammarid amphipods with a few calanoid copepods, and those 46mm and less preyed upon the smaller calanoid copepods with fewer gammarids. The distribution and seasonal abundance of these prey organisms may help to clarify halibut distribution and abundance within the estuary.

Ichthyoplankton

Six taxa of fish larvae from 5 families, and 5 taxa of fish eggs from 5 families were collected during the study period (Table 5). Larval collections were dominated by a complex of goby species that include Arrow goby, Shadow goby (Quietula y-cauda) and Cheekspot goby (Ilypnus gilberti). More than 99% of the adult and juvenile gobies collected were Arrow gobies, as opposed to the other two species, and it is assumed that the larval collections were similarly composed. This complex comprised 86% of the total larvae collected. Longjaw mudsucker larvae comprised 7% of the total demonstrating that spawning occurred during the 1986 season. Whether or not this spawning event contributed significantly to the recruitment of this species is unclear. Three additional species contributed 7% of the total, collectively (Table 4).

Egg collections were dominated by Sciaenidae eggs, a grouping of species that probably includes Queenfish (Seriphus politus), White croaker (Genyonemus lineatus) and other members of the family. This taxonomic group comprised 93%

of the eggs collected. Four other species comprised the remaining 7% (Table 4). Egg diversity was greatest at E3, the site closest to the mouth, where all five species were collected at their highest densities.

Peak densities of goby complex larvae were collected during the November sampling period. This coincides with a spawning peak for this taxon in 1980 (Nordby 1982) at Tijuana Estuary, although maximum spawning peaks occurred in early spring of that year.

Sciaenidae eggs were collected in highest densities in August. This is unusual in that this period is not considered to be a time of Sciaenidae spawning; it usually occurs in late winter-early spring (Nordby 1982).

It was originally proposed that a comparison of flood tide and ebb tide ichthyoplankton be made to test the model of tidal translocation as the primary mechanism controlling ichthyoplankton distribution in Tijuana Estuary. This model was based upon 1980-1981 findings that included nearshore spawning fish larvae in the estuary and estuarine larvae (gobies) nearshore. However, there have been very few specimens of nearshore larvae collected thus far in the estuary. This may be a function of the reduced tidal prism that has resulted from sedimentation of the main channel and sand deposition at the mouth. The fact that the highest diversity and density of eggs were collected at the site near the mouth suggests that a tidal mechanism is still functioning, although this may be to a lesser degree than in 1980-1981.

Zooplankton

Macro-zooplankton populations, collected simultaneously with ichthyoplankton in 505 micron mesh nets, were examined because of their importance as food items for adult and juvenile fishes (M. Hellberg, unpub. data). Although identification has been made only to family level in most cases, gross taxonomic composition and spatial distribution can be demonstrated (Table 6) (dominant copepods were identified to genus level by Dr. C. Por, Hebrew University of Jerusalem).

Fifty forms of zooplankton were identified. Collections were dominated by brachyura zoea which occurred in densities as high as 56 per cubic meter. Calanoid copepods comprised the most diverse group with 18 representative taxa. One species of calanoid copepod, Arcatia sp., occurred in densities as high as 7.6 per cubic meter. Other numerically important zooplankton include decapod zoea and gammarids (Table 6).

The greatest diversity of zooplankton was encountered at station E3, the site closest to the mouth. This is a similar pattern to that demonstrated by ichthyoplankton and lends support to a reduced tidal translocation mechanism.

Densities of brachyura zoea and decapod zoea were greatest at sites E1 and E2 located furthest from the mouth, indicating that these were estuarine spawned as opposed to tidally-transported from nearshore. Densities of calanoid copepods were highest at stations E1 and E3.

Benthic Invertebrates

A total of 41 taxa of benthic invertebrates was collected in 1986-87, with several reported for the first time in samples from Tijuana Estuary (Table 7). Taxa reported for the first time include bivalve molluscs Crassostrea gigas (Japanese oyster) and Zirfaea pilsbryi, the gastropod mollusc Tegula sp., and decapod crustaceans Heptacarpus sp., Cancer gracilis and Calinectes sp.

Collections were dominated by the bivalves Tagelus californianus and Protothaca staminea in the sandy substrates, and by spionid worms in the mud substrates (Table 7). Tagelus californianus occurred in the highest densities at station E2 followed by station E3. Protothaca staminea was also most abundant at site E2 followed by E1. In both cases, highest densities were encountered during summer samples. Species diversity was greatest at site E2 where 26 taxa were collected , followed by E1 with 20, E3 with 13, E4 with 9 and the one-time sampling at E5 with 2.

The occurrence of high densities of the dominant bivalves and high species diversity at the clay/shell substrate of site E2 was unexpected. Tagelus californianus have been collected from Tijuana Estuary in medium to fine sand with highest densities in coarser sediments, while P. staminaea have been taken in very coarse to fine sand with highest densities in finer sediments (Hosmer 1977). Their high relative abundances at site E2 may be due to significant disturbances at other estuarine sites. For example, the main channel was dredged by the U.S. Fish and Wildlife Service in 1984 to remove sediments washed over from adjacent dunes. The mouth region near E3 has also experienced sedimentation from recent flood events (Williams and Swanson 1987) and was bulldozed open in late 1984. The lack of such disturbances at E2 may explain the apparent preference of this habitat relative to other estuarine sites.

Benthic infauna in tidal creeks was low in species diversity with relatively high densities of spionid worms. The sediments at both sites were very fine, anaerobic mud atypical of substrates that support bivalves. Interestingly, at both tidal creek sites, sediments at depths greater than about 15cm changed from fine mud to coarser sand with numerous shells of larger size bivalves. This suggests that under past conditions of greater tidal prism these areas were more productive in terms of benthic infauna.

Population densities of some benthic invertebrates were underestimated using the coring techniques of this study. These include Callianassa californiensis (ghost shrimp), Cerithidea californica (California horn snail) and crab species such as Hemigrapsus oregonensis and Pachygrapsus crassipes, although these latter are not considered infauna. Ghost shrimp burrows were very abundant at sites E1 and E3. When burrows were sampled by means of hand-powered suction pumps, multiple individuals were found in each burrow. Cerithidea snails were very dense in creek bottoms but this was not always apparent in cores. Live crabs were abundant at E2 but were rarely taken in cores. In addition, several specimens of Dendraster excentricus (sanddollar) were taken in seines for adult and juvenile fishes. These were live individuals that ranged in size from about 1cm to 3cm in diameter and may represent the reestablishment of a formerly abundant invertebrate at Tijuana Estuary.

In addition to the sampling conducted in this monitoring effort, R. Duggan sampled the bivalve populations at 5 sites along the main north-south channel as part of his thesis work with Professor D. Dexter (Figure 1). Duggan found 19 species of bivalves at these sites (Table 8). Two species, P. staminea and T. californianus, dominated Duggan's seasonal sampling (Table 9). Densities of the two dominant species dropped significantly from levels in September of 1986 to those in January 1987. However, mean size increased through time in all cases. These data demonstrate the survival and growth of bivalve recruits following reinstatement of tidal flushing.

On December 31, 1986 and again on January 1, 1987, tides of 7.8 ft MLLW washed dune sand into the channel at the site of station E1. Although not quantified, it is estimated that 4 to 6 inches of sand were deposited in the channel. A comparison of the benthic invertebrates at E1 and in an adjacent section of the channel not affected by the wash-over illustrates the immediate effects of such sedimentation (Table 10). The dominant bivalves at E1 were eliminated while densities of other invertebrates were considerably less than in the adjacent area. It is obvious that even short-term sedimentation events are very harmful to the benthic infauna.

Two new areas to the south of the mouth (Figure 1) were sampled for invertebrates in March, 1987. This channel has been receiving reduced tidal flows due to sedimentation at the mouth, and portions of it were dredged in 1986. Station F was in an undredged part of the channel while station G was located within a dredged reach. Thus, a comparison of the effects of dredging on channel invertebrates can be made. The results of the southern channel survey (Table 11) demonstrate a different bivalve community than that found in the northern arm. The dominant species is Cryptomya californica while Tagelus californianus and Protothaca staminea are relatively minor species. In addition, the mean size of Tagelus californianus is large (54mm) indicating that these specimens are several years old and thus represent successful recruitment following mouth opening in December, 1984. Large Macoma nasuta were also encountered, as well as smaller individuals that lowered the mean size of this species to 21.3mm. Cryptomya californica, on the other hand, are newly recruited to this area as indicated by the mean size of 8.75mm.

The comparison of dredged and undredged sites shows the short-term impact of such activities of the channel biota. Site G contained very few bivalves and those present represent new recruits. The rate of colonization of this area will be followed in the second year of this program. The entire north arm of the estuary was dredged in April, 1987 by the U.S. Fish and Wildlife Service to remove sedimentation due to dune wash-over and improve the tidal prism. The positive effects of dredging to improve tidal flushing must be weighed against the short and long-term impacts to channel organisms.

Conclusions

The small tidal wetlands typical of southern California are primarily influenced by seawater with only seasonal freshwater input. Thus, channel biota are dominated by marine forms. Unlike estuarine organisms in areas of continuous freshwater input, which are adapted to a range of salinities, deviation from seawater salinities is often lethal. Recolonization from an oceanic source may be rapid, but reestablishment of a stable community may take several years, especially if environmental perturbations, such as drought or flooding, continue.

At Tijuana Estuary, closure to tidal flushing and coincidental drought resulted in the elevation of water salinities to greater than 100ppt and the drying of intertidal habitat. Nearly all benthic invertebrates were killed, with the exception of spionid worms. The immediate effect on channel fishes is less clear. Data from a graduate level SDSU Estuarine Ecology class (seven sites, sampled once each over three dates) revealed six species - Topsmelt (Atherinops affinis), California killifish (Fundulus parvipinnis), Longjaw mudsucker (Gillichthys mirabilis), Arrow goby (Clevelandia ios), Cheekspot goby (Ilypnus gilberti), and Striped mullet (Mugil cephalus). If sampling was careful and complete, the notable absence of flatfishes California halibut (Paralichthys californicus) and Diamond turbot (Hypsopsetta guttulata), and the benthic Pacific staghorn sculpin indicates an early, negative response of these species to rising salinities.

Monitoring of fishes and invertebrates at Tijuana Estuary was initiated in June, 1986, approximately 18 months following reopening of the estuary mouth. The benthic invertebrate community was dominated by small (<40mm) Tagelus californianus and Protothaca staminea. The size of these bivalves indicates that these are recent recruits, less than one year in age. Thus, 18-24 months after the return to normal salinities, the benthic community was still unstable and susceptible to catastrophic events.

The fish community showed a less obvious response to the stressful conditions of mouth closure. During 1986-87 flatfish populations appeared to recover with numerous small individuals present in the main channels. However, populations of Longjaw mudsucker were still low, occurring in only two samples over the entire year and in low relative abundance. Evidence suggests that this population depression was a direct result of high salinities.

The effects of sedimentation on estuarine organisms has been well documented (Onuf and Quammen 1983, Darnell 1976, Sherk 1971). Sedimentation affects filter-feeding benthic invertebrates by direct burial, habitat destruction, impaired respiration, impaired feeding and excretory functions, retarded egg development, and reduced growth and survival of larval stages (Sherk 1971). Fishes are most affected by loss of invertebrate food items, interference with respiration, and destruction of demersal eggs (Morton 1977).

The immediate and short-term effects of sedimentation examined in this study resulted in the near total extirpation of benthic infauna in small isolated areas. The impact on fishes was less dramatic, due to their mobile nature. However, densities and diversity were low in areas affected by dune wash-over. Whether this was due to mortality or avoidance of the area is not known. A sedimentation event during spawning of a species with demersal eggs, such as the Arrow goby and Longjaw mudsucker, could lead to depressed population levels.

Recommendations

1. Assess effects of dredging.

In April, 1987 a contractor to the U.S. Fish and Wildlife Service dredged the main north-south channel of the estuary to remove accumulated sediments and increase tidal prism. Additional dredging is planned for later in 1987. Due to the large scale of this operation, many channel organisms and their habitat will be eliminated. It is vital that the immediate effects of dredging be assessed, i.e. the survival or mortality of infauna and associated effects on fishes. Longterm effects such as rates of recolonization and population stabilization can only be documented after the hydrological modifications to the system are completed. This work will begin with the 1987-88 NOAA-OCRM-MEMD project.

2. Maintain tidal flushing while minimizing the frequency of maintenance dredge operations.

The importance of tidal flushing to the channel organisms cannot be overemphasized. These are marine species dependent upon tides to supply nutrients, moderate temperatures, deliver dissolved gases and dilute waste products.

Despite the immediate damage due to dredging, the estuarine mouth should be maintained open if it closes. While it has been suggested that reduced tidal circulation may be desirable for some salt marsh plants (Zedler and Covin, 1987), the overall management goals of the system must be defined. A reduced tidal influence may favor the cordgrass-light-footed clapper rail association over the pickleweed-Belding's Savannah sparrow association. However, the invertebrate food supply of the clapper rail may be negatively affected by this action while the insect-dominated foods of the Belding's Savannah sparrow might be less so.

Efforts should be made to stabilize the hydrology of the system so that repeated dredging is not necessary. With the current cycle of sedimentation and dredging, the biological communities at Tijuana Estuary are in a constant state of flux, with many species bordering on local extinction. A one-time massive dredging oiperation, while extremely harmful in the short term, might be the most beneficial in the long term.

3. Evaluate impacts of wastewater discharges to Tijuana Estuary.

Other hydrological issues include the management of freshwater and wastewater inflows. Currently, renegade wastewater from Mexico flows into the Tijuana Estuary. These inflows affect the system in two ways: the fresh water changes a seasonal stream to one that flows year-round and potentially toxic compounds in the wastes are discharged to the estuary. Year-round reservoir discharge to the San Diego River marsh resulted in a shift in the vegetation community of that system from salt marsh to brackish marsh dominated by cattail (_Typha_ _domingensis_) (Zedler and Beare, 1986). The impact of toxic compounds such as selenium on California wetlands is currently being investigated. The effects of wastewater addition to the Tijuana Estuary should be carefully monitored and the discharge controlled to avoid such potential impacts.

Acknowledgements

This research was funded by NOAA Office of Ocean and Coastal Resource Management, Marine and Estuarine Management Division Grant No. NA86AA-D-CZO 16. I gratefully acknowledge S. Perry, J. Covin, M. Hellberg, R. Duggan, A. Setran, M. Drawbridge and T. Griswold for field assistance; R. Duggan and M. Hellberg for the use of their data; K. Dyke for laboratory analysis of fishes and invertebrates; and, J. DeWald for report production assistance.

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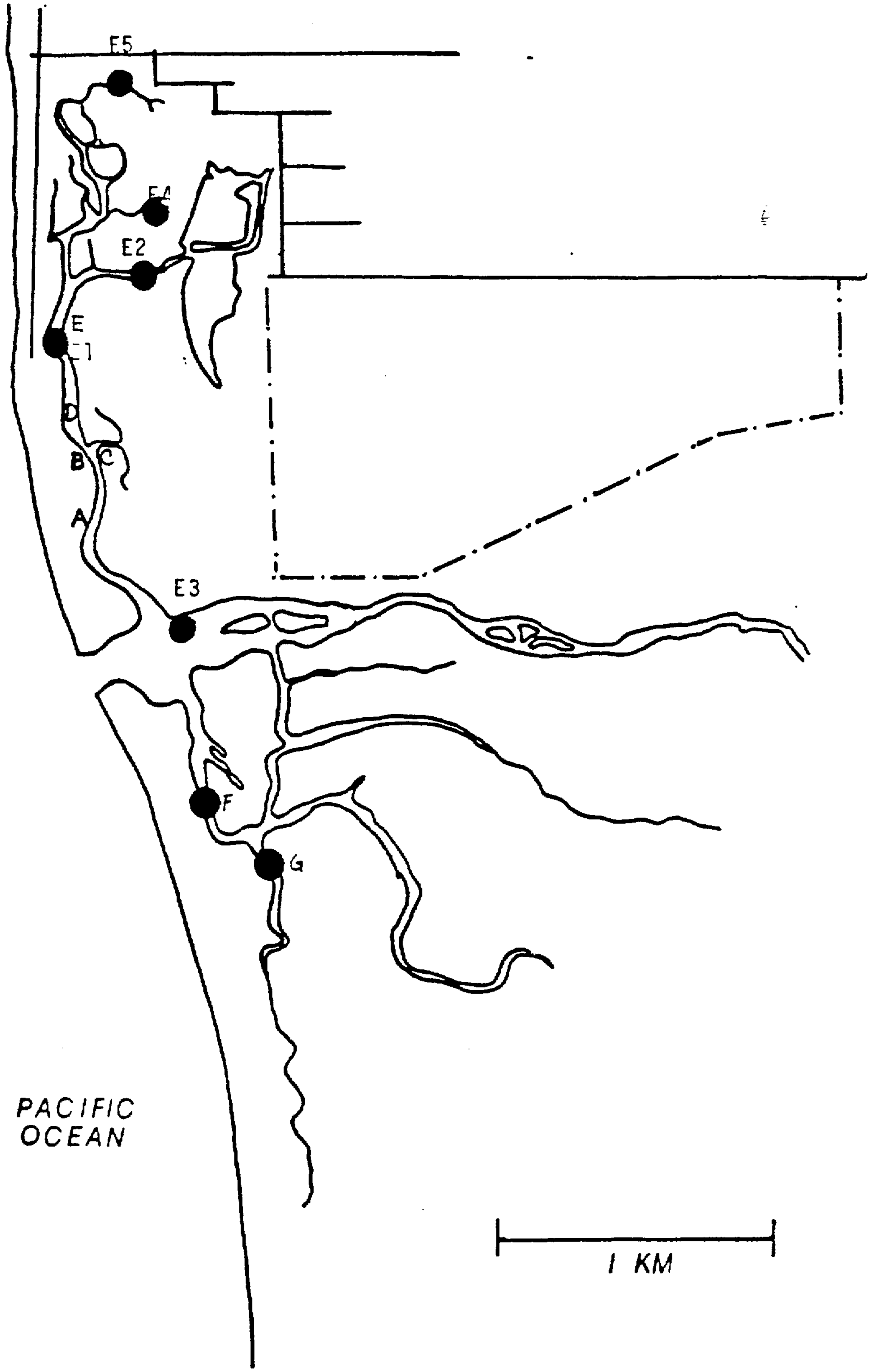


Figure 1. Sampling stations at Tijuana Estuary, CA. Sites A-G from R.Duggan in Progress.

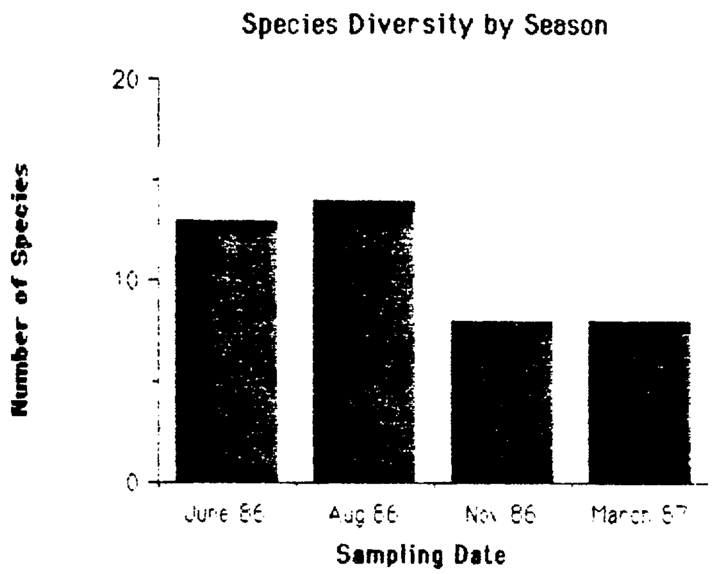


Figure 2. Species diversity of adult and juvenile fishes collected on 4 dates at Tijuana Estuary, CA. in 1986-87.

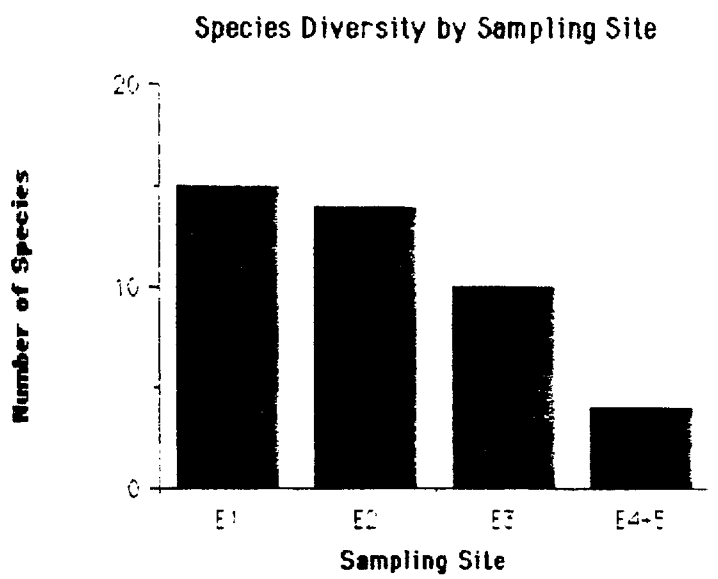


Figure 3. Species diversity of adult and juvenile fishes collected from 5 sites at Tijuana Estuary, CA. in 1986-87.

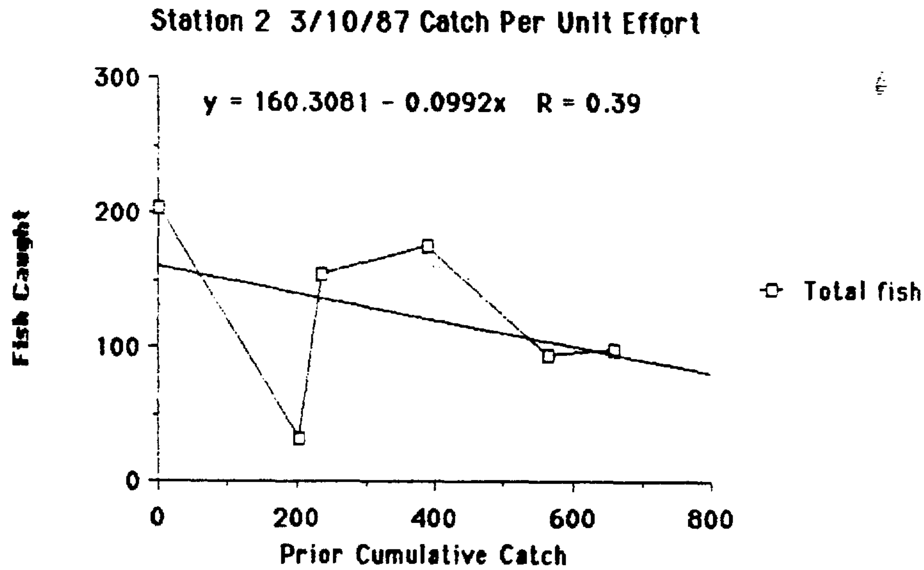


Figure 4a. Catch per unit effort of adult and juvenile fishes at station E2 on 3/10/87.

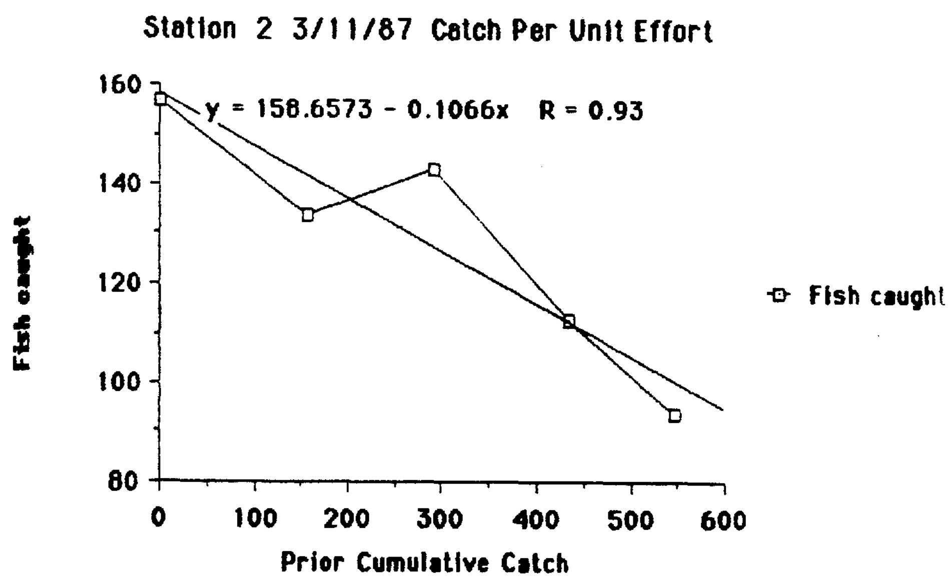


Figure 4b. Catch per unit effort of adult and juvenile fishes at station E2 on 3/11/87.

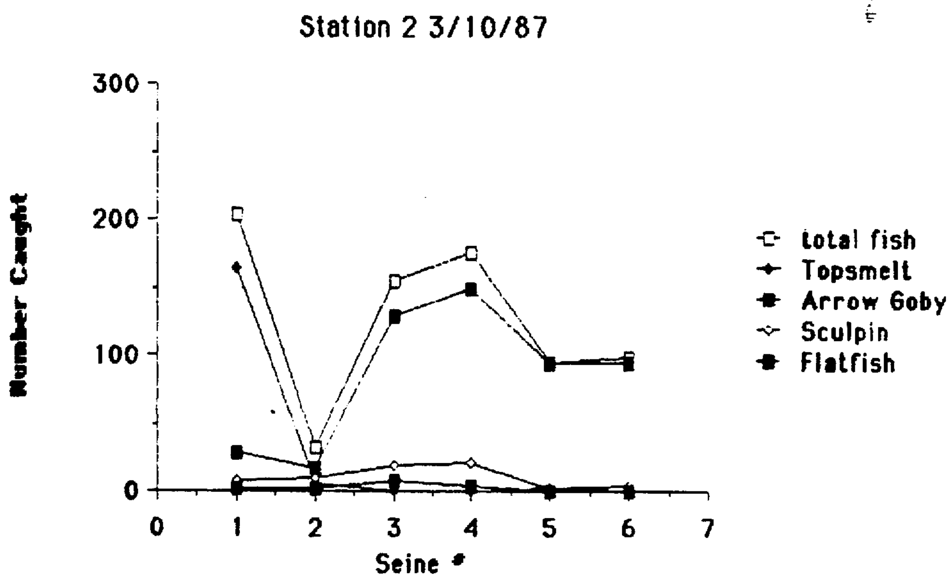


Figure 5a. Species composition of repeated seinings at station E2 on 3/10/87.

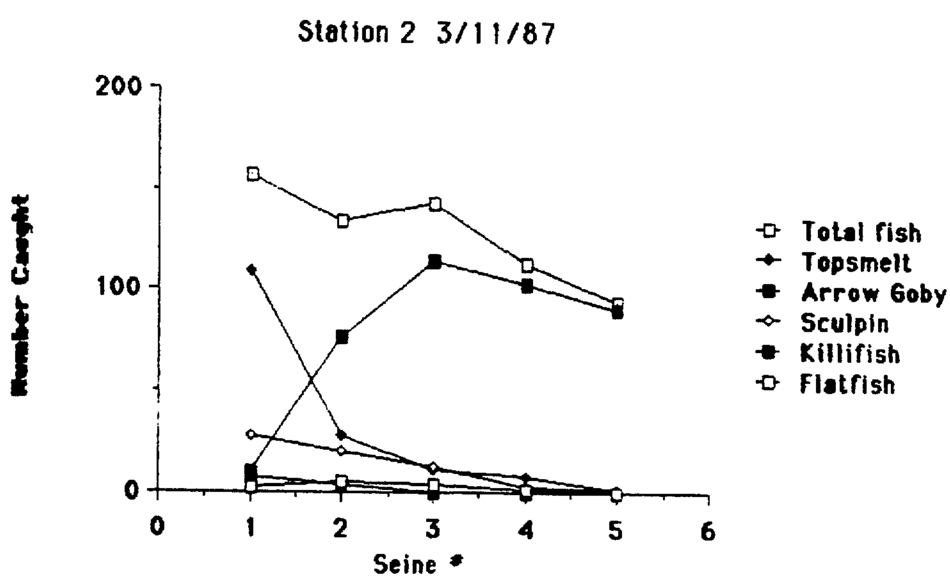


Figure 5b. Species composition of repeated seinings at station E2 on 3/11/87.

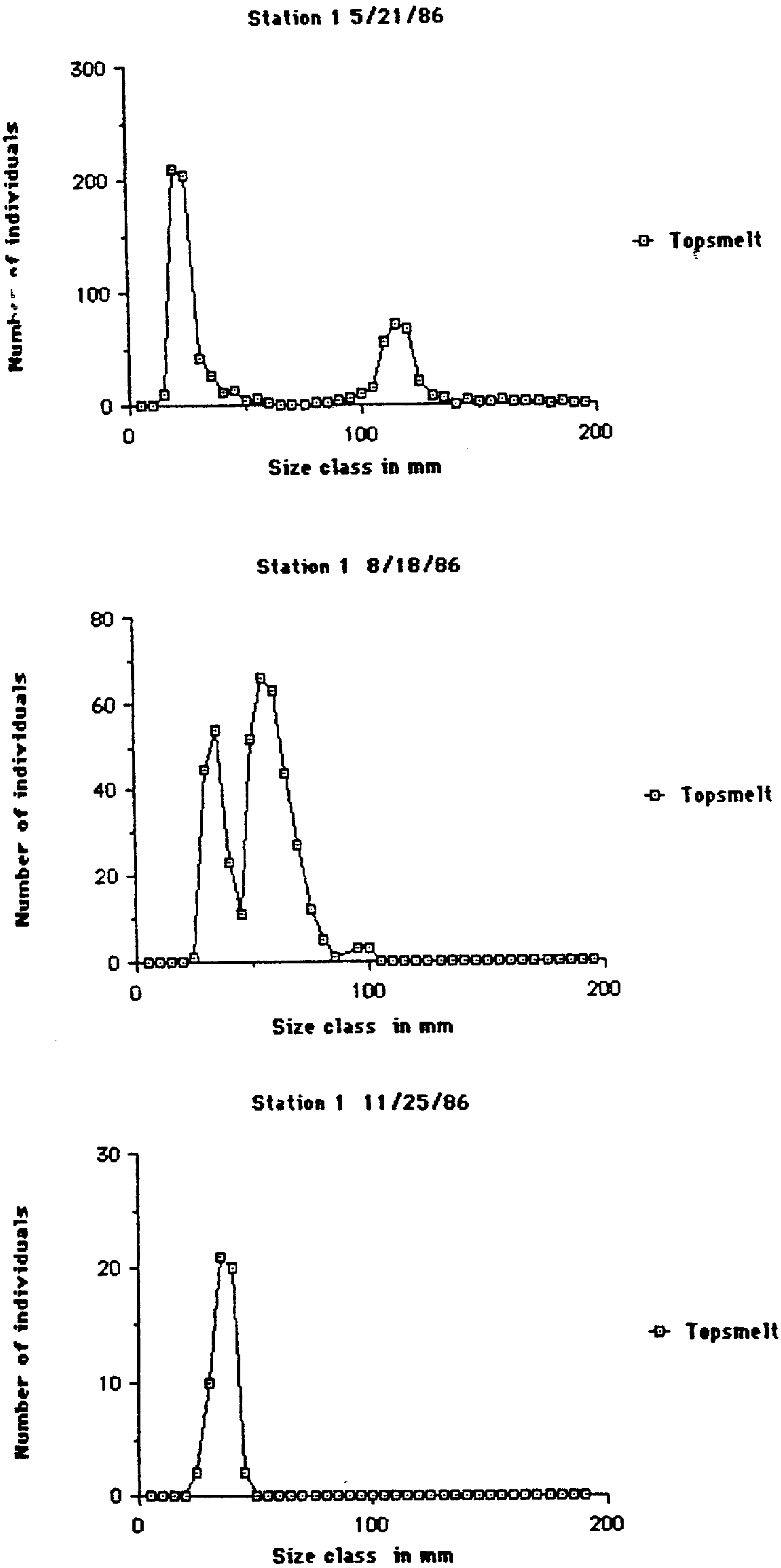


Figure 6. Size frequency analysis of Topsmelt at station E1.

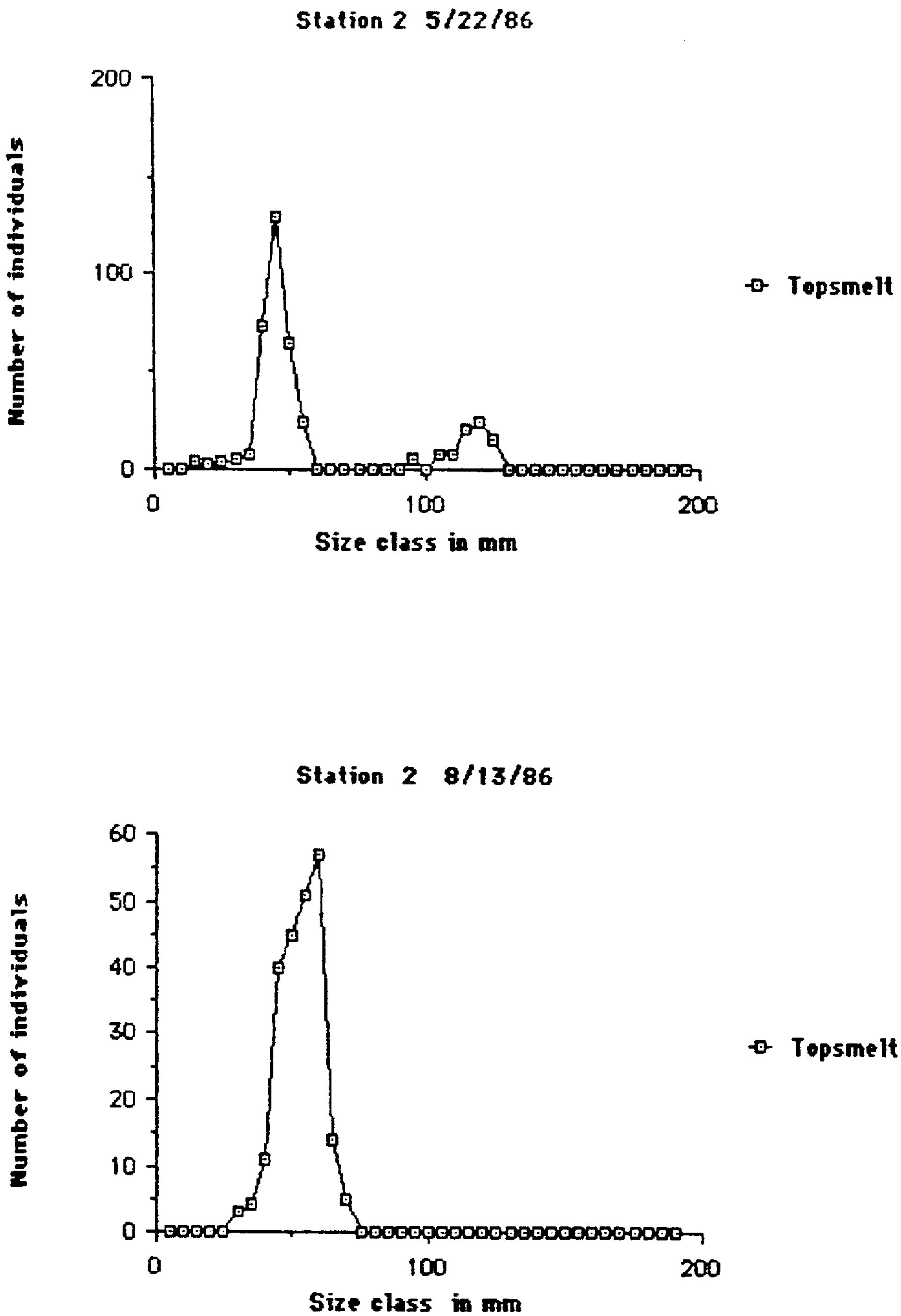
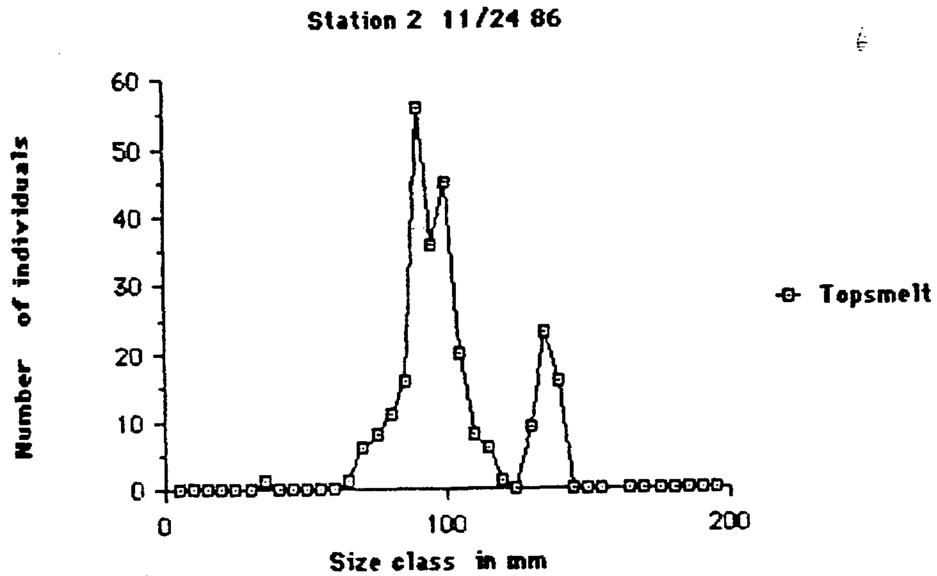


Figure 7. Size frequency analysis of Topsmelt at station E2.



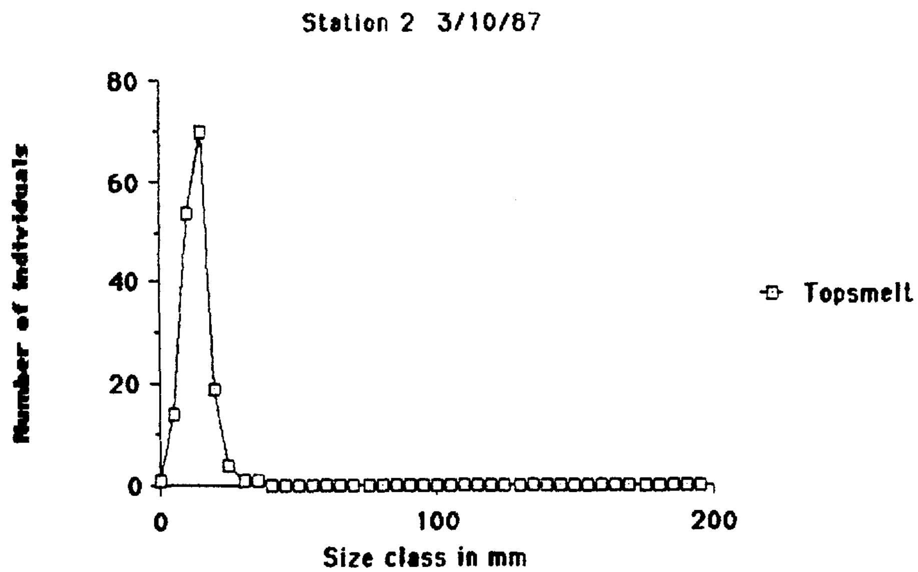
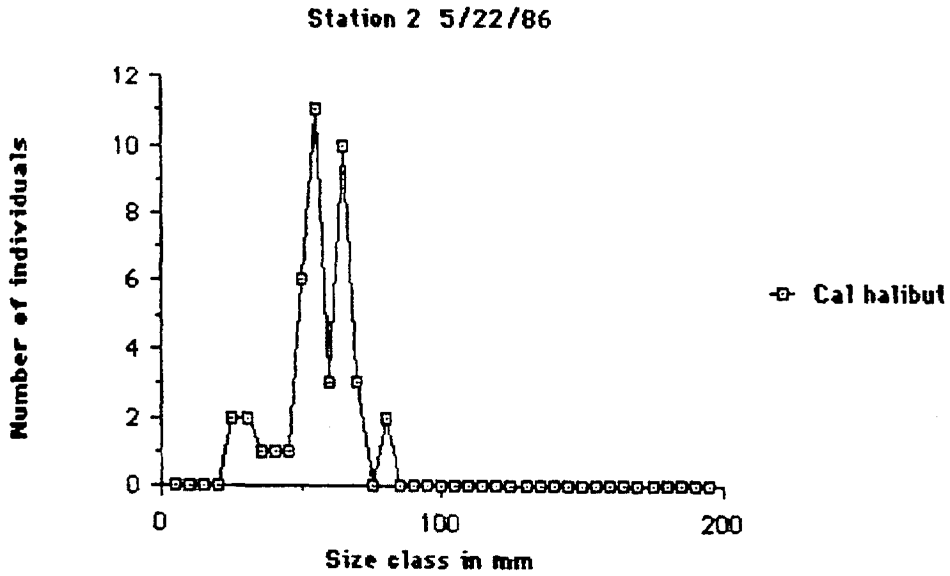


Figure 7. Continued.



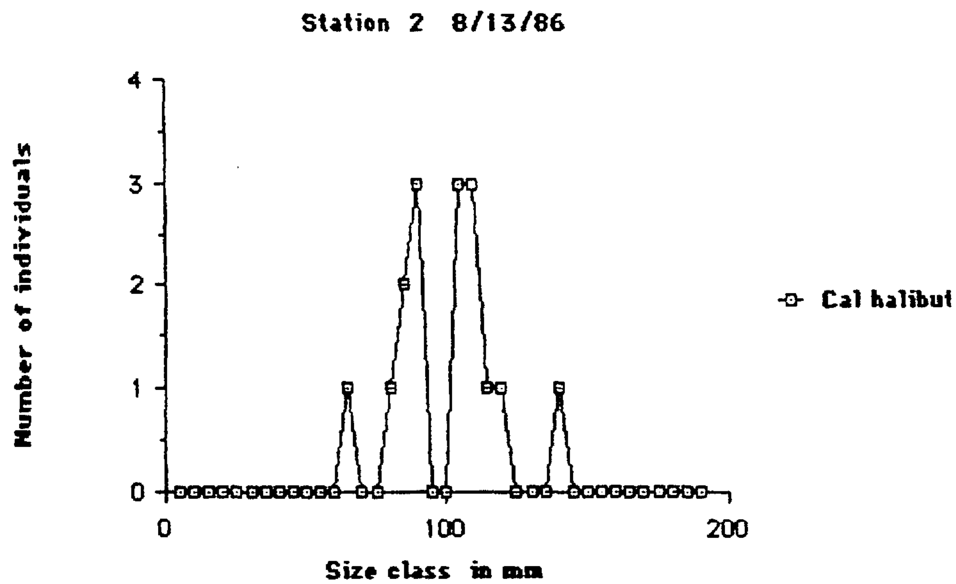
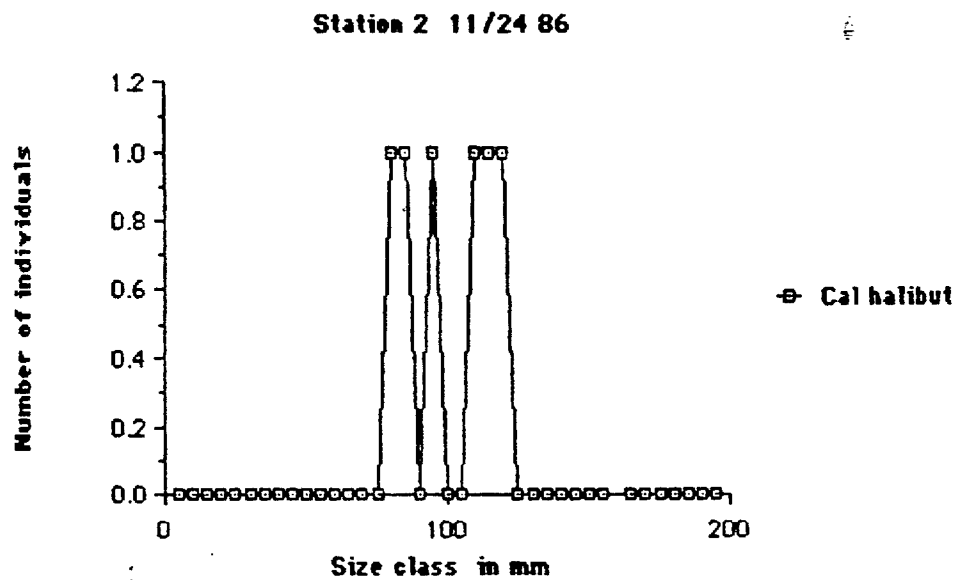


Figure 8. Size frequency analysis of California halibut at station E2.



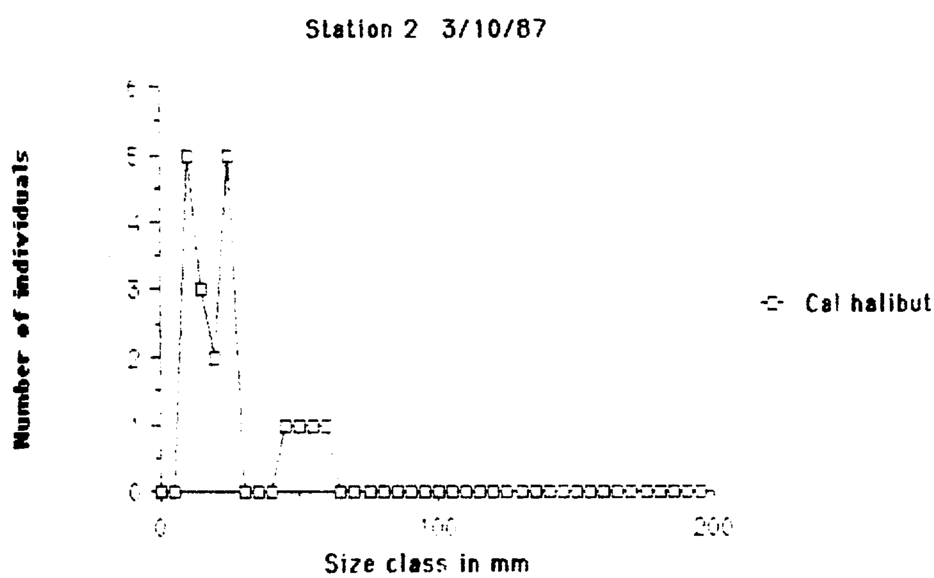


Figure 8. Continued

Table 1. Taxonomic composition, relative abundance and densities of adult and juvenile fishes collected at 5 sampling sites at Tijuana Estuary, CA. Densities ($\#/m^3$) are shown in parentheses.

		Number collected and density per sampling site per date Density ($\#/m^3$) in parenthesis							
		E1				E2			
Taxon	Common Name	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Atherinidae									
Atherinops affinis	Topsmelt	3629(23.0)	401(9.5)	55(0.8)		4340(14.5)	231(3.5)	584(6.5)	172(1.8)
Blenniidae									
Hypsoblennius gilberti	Rockpool Blenny		1(<0.1)						
Hypsoblennius jenkinsi	Mussel Blenny		1(<0.1)						1(<0.1)
Bothidae									
Paralichthys californicus	California Halibut	33(0.2)	3(<0.1)	3(<0.1)	1(<0.1)	43(0.1)	14(0.2)	6(<0.1)	18(0.2)
Cottidae									
Leptocottus armatus	Pacific Staghorn Sculpin	186(1.2)	4(<0.1)	2(<0.1)	15(0.2)	16(<0.1)			64(0.67)
Artedius sp.	Sculpin	2(<0.1)							
Cyprinodontidae									
Fundulus parvipinnis	California Killifish		58(1.4)	77(1.1)		6(<0.1)	155(2.3)	12(0.1)	
Engraulididae									
Anchoa compressa	Deep Body Anchovy					3(<0.1)		2(<0.1)	
Girellidae									
Girella nigricans	Opaleye		9(0.2)				70(1.1)		
Gobiidae									
Clevelandia ios	Arrow Goby	174(1.1)	5(0.1)	2(<0.1)	4(<0.1)	5(<0.1)	6(<0.1)		608(6.4)
Ilypnus gilberti	Cheekspot Goby	1(<0.1)	7(0.2)						1(<0.1)
Quietula y-cauda	Shadow Goby								
Gillichthys mirabilis	Longjaw Mudsucker						39(0.6)		
Mugilidae									
Mugil cephalus	Striped Mullet					3(<0.1)			
Pleuronectidae									
Hypsopsetta guttulata	Diamond Turbot	1(<0.1)	1(<0.1)		2(<0.1)	4(<0.1)			10(0.1)
Pleuronichthys ritteri	Spotted Turbot		3(<0.1)						1(<0.1)
Rhinobatidae									
Rhinobatos productus	Shovelnose guitarfish		1(<0.1)						
Serranidae									
Paralabrax clathratus	Kelp Bass							1(<0.1)	
Sciaenidae									
Seriphus politus	Queenfish	1(<0.1)							
Syngnathidae									
Syngnathus leptorhynchus	Bay Pipefish	5(<0.1)	1(<0.1)						1(<0.1)

*Station 5 = Sampled in lieu of Station 4 during fall sampling period

Table 1. Continued.

	E3			E4		E5
Spring	Summer	Fall	Winter	Spring	Summer	Fall
1062(7.1)	349(14.2)		1(<0.1)	313(104.3)		
11(0.1)		1(<0.1)	1(<0.1)			
80(0.5)		10(0.4)				
23(0.15)	349(14.2)	110(4.5)	1(<.01)	3(1.0)	176(9.5)	
	1(<0.1)					
1043(7.0)	6178(252)	204(8.3)	302(12.0)	360(120)	10(0.5)	23(5.8)
25(0.2)		12(0.5)	2(<0.1)			
3(<0.1)						
				2(0.7)		
7(<0.1)			9(0.4)			
		1(<0.1)				

Table 2. Physical characteristics of 5 sampling sites at Tijuana Estuary, CA.

Sampling period	$\bar{X}$ Dissolved O_2(ppm)	$\bar{X}$ Temperature	Salinity (ppt)	Time	Channel morphometry (width x depth)	Channel substrate
6/86						
Station E1	6.2	20.5	35	1045	13m x .75m sloping to steep sides	sand
Station E2	6.5	27	38	1200	12m x 1m steep sides	clay/shells
Station E3	4	22	38	1130	10m x .5m sloped sides	sand/mud
Station E4	saturated	27	37	1200	2m x 0.1m sloped sides	mud
8/86						
Station E1	6	23	34	1440	14m x .5m	
Station E2	2	25	34	1000	12m x .3m	
Station E3	saturated	29	34	1100	10m x .3m	
Station E4	N.D.	N.D.	N.D.	1300	2m X .5m	
11/86						
Station E1	saturated	16.0	33	1110	13m x .5m	
Station E2	8.1	16.5	34	1330	12m x .75m	
Station E3	8.15	15	34	1015	10m x .3m	
Station E5	8.0	16.5	33	1200	2m x .1m	
3/87						
Station E1	7.6	15.0	32	1045	13m x .5m	
Station E2	7.0	12.5	34	1340	13m x .45m	
Station E3	saturated	20.5	34	1400	10m x .3m	

Table 3a. Comparison of adult and juvenile fishes and ichthyoplankton collected from Station E1 on consecutive days. Numbers in parentheses = mean density.

		Number collected	
		11/25	11/26
ADULTS AND JUVENILES			
Atherinops affinis	Topsmelt	55	56
Clevelandia ios	Arrow Goby	2	0
Paralichthys californicus	California Halibut	3	2
Leptocottus armatus	Pacific Staghorn Sculpin	2	1
Fundulus parvipinnis	California Killifish	77	29
Hypsopsetta guttulata	Diamond Turbot	0	2
LARVAE			
Atherinops affinis	Topsmelt	0	7(0.02)
Artedius sp.	Sculpin	9(0.02)	0
Goby complex	Gobies	300(0.6)	246(0.6)
Gillichthys mirabilis	Longjaw Mudsucker	6(0.01)	4(0.01)
EGGS			
Citharichthys spp.	Sanddab	4(0.04)	2(0.008)
Sciaenidae	Croakers	4(0.01)	2(0.008)

Table 3b. Comparison of adult and juvenile fishes collected from Station E2 on consecutive days.

		Number collected	
		3/10	3/11
ADULTS AND JUVENILES			
Atherinops affinis	Topsmelt	172	157
Clevelandia ios	Arrow Goby	608	502
Paralichthys californicus	California Halibut	17	*
Leptocottus armatus	Pacific Staghorn Sculpin	64	68
Fundulus parvipinnis	California Killifish	-	11
Hypsopsetta guttulata	Diamond Turbot	10	*
Hypsoblennius jenkinsi	Mussel Blenny	1	-
Ilypnus gilberti	Cheekspot Goby	1	-
Syngnathus leptorhynchus	Bay Pipefish	1	-
Flatfish combined			13

Table 4. Halibut gut analysis.

Size of Specimen	Gut Contents
1) 17 mm	10 calanoid copepods
2) 17 mm	6 gammarids amphipods, 5 calanoid copepods
3) 18 mm	4 gammarid amphipods, 50 calanoid copepods
4) 24 mm	20 calanoid copepods + fragments
5) 34 mm	6 gammarid amphipods, 75 calanoid copepods
6) 43 mm	5 gammarids amphipods, 52 calanoid copepods
7) 46 mm	20 gammarid amphipods, 7 calanoid copepods + fragments
8) 46 mm	200+ calanoid copepods
9) 49 mm	4 gammarid amphipods + fragments
10) 60 mm	34 gammarid amphipods + fragments
11) 61 mm	34 gammarid amphipods + fragments
12) 61 mm	14 gammarid amphipods
13) 63 mm	21 gammarid amphipods + fragments
14) 72 mm	2 Arrow Goby 30 mm, 17 mm
15) 73 mm	2 unidentified fish, 5 gammarid amphipods
16) 104 mm	1 Arrow Goby, 26 mm
17) 105 mm	1 Arrow Goby, 38 mm
18) 111 mm	3 Arrow Goby, 15 mm, 13 mm, 18 mm
19) 113 mm	3 Arrow Goby, 15 mm, 13 mm, 15 mm, 5 Topsmelt, 19 mm, 22 mm, 20 mm, 12 mm, 23 mm
20) 149 mm	All contents partially digested - non-identifiable

Table 5. Taxonomic composition, number collected and mean density (#/m^3) per sample of fish eggs and larvae collected at 3 sampling sites at Tijuana Estuary, CA. Density figures in parenthesis.

LARVAE			E1				E2			E3	
Taxon	Spring	Summer	Fall (11/25)	Fall (11/26)	Winter	Summer	Fall	Winter	Summer	Fall	Winter
Atherinidae											
Atherinops affinis		1(0.001)		7(0.02)							7(0.02)
Cottidae											
Artedius sp.		2(0.005)	9(0.02)			25(0.08)			2(0.005)	2(0.07)	
Gobiidae											
Goby complex		2(0.005)	300(0.6)	246(0.6)	198(0.3)	3(0.008)	4(0.03)		4(0.01)		11(0.03)
Gillichthys mirabilis			6(0.01)	40(0.1)	15(0.02)						6(0.02)
Pleuronectidae											
Pleuronichthys ritteri										1(0.01)	
Engravlidae											
Engravlis mordax					4(0.005)						
EGGS											
Bothidae											
Citharichthys spp.	10(0.02)		4(0.04)	2(0.008)	6(0.08)	4(0.01)	5(0.01)			2(0.07)	2(0.005)
Ophidiidae											
Odophidium scrippsi									26(0.06)		
Pleuronectidae											
Pleuronichthys ritteri									1(0.002)		
Sciaenidae spp.			7(0.02)	4(0.01)	8(0.01)	2(0.008)	5(0.01)		665(1.5)		1(0.002)
Scombidae											
Scomber japonicus										1(0.002)	

Table 6. Mean densities (n=3) of zooplankton collected from 3 sampling stations at Tijuana Estuary July 22 through August 4, 1986. Data from M. Hellberg, unpublished.

	E1		E2		E3	
	Flood Tide	Ebb Tide	Flood Tide	Ebb Tide	Flood Tide	Ebb Tide
<u>Brachyura zoea</u>						
A	10	56.1	6.0	12.8	0.0	1.7
B	1.8	9.3	1.3	4.1	0.02	0.3
C			0.01		0.01	
<u>Brachyura megalops</u>						
A					0.01	
B			0.01			
<u>Decapod zoea</u>						
A	0.4	0.62	1.22	1.2	0.03	0.02
B	0.01	0.04	0.02		2.0	0.23
C		0.01			0.01	
<u>Decapod megalops</u>						
A					0.005	0.01
<u>Calanoid copepod</u>						
A Arcatia sp.	7.6	7.1	0.63	1.1	3.6	0.31
B Labidocera sp.					0.005	
C Pseudodiaptomus sp.	0.01	0.02	0.01		0.005	0.01
D Centropages sp.	0.01		0.02		0.06	0.01
E Pseudodiaptomus sp.					0.02	0.004
F Labidocera sp.	0.01	0.02	0.21	0.74		0.01
G Pseudodiaptomus sp.	0.02	0.01	0.02	0.14	0.01	
H Centropages sp.	0.01		0.02	0.03	0.01	
I						
J					0.06	0.01
K					0.02	0.004
L						0.004
M					0.02	
N					0.02	
O					0.01	
P					0.01	
Q					0.005	
R					0.005	
<u>Chaetognath</u>	0.05	0.04	0.24	0.15	0.01	
<u>Gammarid</u>						
A	0.18	0.05	0.01	0.02	0.005	0.004
B	0.14	0.04	0.24	0.64	0.09	0.10
C					0.05	0.004
D	0.01	0.01			0.01	
<u>Hydrozoa medusae</u>						
A			0.01			
B					0.005	
C						0.01
D	0.06	0.01				

Table 6. (Cont.)

	E1		E2		E3	
	Flood Tide	Ebb Tide	Flood Tide	Ebb Tide	Flood Tide	Ebb Tide
Isopod						
A				0.01	0.01	
B						0.004
C					0.005	
Balanus nauplius			0.01			
Bivalve	0.02	0.02	0.01			
Cyclopoid copepod						
A			0.01	0.01		
B	0.01	0.01				
C		0.01	0.01	0.03		0.01
Harpacticoid copepod tisbe sp.			0.01	0.01		
Hyperiid						
Pychogonid						0.005
Worm-like forms						
A					0.01	
B					0.01	
C					0.01	
D	0.01					
E			0.01			
F				0.01		
Mysid larvae	0.02	0.01	0.02	0.16	0.06	0.02
Unknown					0.04	0.004
Copepod nauplius					0.01	0.004

Table 7. Benthic invertebrates collected at 5 sampling sites at Tijuana Estuary, CA. Quarterly sampling periods are designated as Sp = Spring; S = summer; F = Fall; W = winter. Numbers in parentheses are mean densities (#/m^2) to a 20 cm depth. + = Present in samples.

Taxon		E1				E2				E3				E4	
	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F
SIPUNCULID WORMS		2(60)		1(8)											
ECHINOID ECHINODERMS															
Dendraster excentricus		3(91)									2(48)				
POLYCHAETE WORMS															
Glyceridae	+	1(30)	1(20)												
Nereidae							1(30)							5(121)	
Spionidae				1(8)	+								13(525)	10(404)	12(485)
Polynoidae			1(20)												
Unknown	+	1(30)							+				3(121)		
Nephtyidae												1(19)			
Capitellidae				1(8)					+						
BIVALVE MOLLUSCS															
Tagelus californianus		16(485)	32(146)	1(8)		126(3318)	18(595)	71(401)	+	95(2303)		8(150)			
Macoma nasuta						6(181)	3(91)	4(23)							
Ostrea lurida						1(30)		1(6)							
Solen rosaceus															
Crassostrea gigas						1(30)									
Mytilus edulis					+	2(60)			+						
Protothaca staminea		23(697)	4(81)		+	30(909)	15(455)	28(158)	+	8(264)		1(19)			
Protothaca sp.						1(30)									
Zirfaea pilsbryi		1(30)			+				+						
Laevicardium substriatum	+	3(91)			+			13(73)	+						
Chione californensis		1(30)			+										
Mactridae					+			1(6)							
Saxidomus nuttalli								1(6)							
Florimetis obesa															
GASTROPOD MOLLUSCS															
Cerithidea californica	+		5(101)	1(8)		8(212)					2(48)	4(162)	1(19)	5(202)	3(182)
Nassarius tegula	+		5(101)		+	6(182)									
Acteocina faculta											1(24)				
Haminoea virescens											4(97)				
Crepidula fornicata							1(30)								
Tegula sp.							1(30)								
Olivella sp.														2(81)	
Melampus olivaceus														2(81)	

Table 7. (Cont.)

Taxon	E1				E2				E3				E4		
	Sp	S	F	W	Sp	S	F	W	Sp	S	F	W	Sp	S	F
DECAPOD CRUSTACEANS															
Herptacarpus sp.			3(61)			6(182)	4(121)								
Hemigrapsus oregonensis		1(30)	1(20)			4(121)								3(121)	
Portunas xantusi						2(61)									
Callianassa californiensis	+	3(91)	1(20)	1(8)					+	1(24)					
Cancer gracilis		2(61)			+										
Calinectis sp.		1(30)													
Pachygrapsus crassipes									+				+		
Uca crenulata					+										
ISOPOD CRUSTACEANS															
Rocinela sp.						1(30)									
BRACHIOPODA															
Glottidia albida			1(30)												

Table 8. Bivalves collected from 5 main channel sampling sites at Tijuana Estuary, CA. Data from Duggan, in prog.

Tagelus sp.

Protothaca staminea

Laevicardium substriatum

Solen rosaceus

Macoma nastuta

Zirfea pilsbryi

Cryptomya californica

Saxidomas nuttalli

Sanguinolaria nuttalli

Chione undatella

Chione californica

Mactra californica

Florimetis obesa

Copperella subdiaphinia

Lyonsia californica

Petricolas sp.

Platydon cancellatus

Tellina modesta

Tellina carpenteri

Table 9. Densities of dominant bivalves collected from 5 main channel sites at Tijuana Estuary during September 1986 and January 1987 (Data from Duggan, In progress). Density expressed as #/m^2 to a 20 cm depth.

	Site A						Site B						Site C					
	Sept. '86			Jan. '87			Sept. '86			Jan. '87			Sept. '86			Jan. '87		
Taxon	#	density	X size	#	density	X size	#	density	X size	#	density	X size	#	density	X size	#	density	X size
Protothaca staminea	109	2,642	9.39	90	1,019	10.8	43	1,042	10.03	77	871.5	10.7	136	5,495	7.97	69	780	10.6
Tagelus californianus	180	4,363	31.82	167	1,890	38.4	91	2,206	35.63	32	362.2	37.8	44	1,778	25.89	30	339	33.6
Laevicardium substriatum	18	436	12.72				8	194	14.9	11			8	323	13.23	5		
Cryptomya californica	1	24					4	97	15.46				3	121	4.57	1		
Solen rosaceus	6	145	28.15	2			1	24										
Macoma nasuta	3	73	23.9	3			3	73		1			2	81	16.2			
Chione undatella	1	24								2								
Zirfaea sp.				3				73	30.43	3								
Sanguinolaria nuttalli							1	24										
Musculus senhousei										1				40				
Saxidomas				3												1		
Florimeti																1		
Copperella																2		
Lyonsra																1		
Petricola																2		

Ext. of Table 9

Site D						Site E					
Sept. '86			Jan. '87			Sept. '86			Jan. '87		
#	density	$\overline{X}$ size	#	density	$\overline{X}$ size	#	density	$\overline{X}$ size	#	density	$\overline{X}$ size
19	461	9.87	11	124.5	11.2	5	121	7.04	0		
42	1,018	34.87	8	90.5	42.8	86	2,085	34.02	45	509.3	39.7
1	24										
						1	24				
1	24					1	24				
			1			2	80	54.05	23		
			1						1		

Table 10. Benthic invertebrates collected from areas impacted by sedimentation from dune wash-over (E1) and adjacent sites not impacted (E1a) in March 1987.

Species	Site E1 # ($\bar{X}$ density) n = 7	E1a # ($\bar{X}$ density) n = 4
BIVAVE MOLLUSCS		
Tagelus californicus	0	14 (198)
Protothaca staminea	0	2 (28)
Macoma nasuta	0	2 (28)
GASTROPOD MOLLUSCS		
Cerithidea californica	1 (8)	0
SIPUNCULID WORMS	1 (8)	7 (99)
POLYCHAETE WORMS		
Nephtyidae	0	2 (28)
Capitellidae	1 (8)	9 (127)
Spionidae	1 (8)	7 (99)
DECAPOD CRUSTACEANS		
Callianassa californiensis	1 (8)	3 (42)

Table 11. Mean densities (n=5) of bivalves collected at a dredged (Site G) and non-dredged (site F) area of southern channel at Tijuana Estuary, CA.

	Site F			Site G		
	#	$\bar{X}$ density	$\bar{X}$ site	#	$\bar{X}$ density	$\bar{X}$ site
Tagelus californicas	11	124.5	54	1	18.9	-
Cryptoma californica	112	1267.7	8.75	3	56.6	8.33
Protothaca staminea	3	33.9				
Macoma nasuta	15	169.7	21.3			
Laevicardium substriatum	5	56.7	7.4			
Tellina carpenteri	1	11.3				
Musculista senhousii	1	11.3				

REPORT DOCUMENTATION PAGE | 1. REPORT NO. | 2. | 3. Recipient's Accession No.

4. Title and Subtitle

Monitoring of Fishes and Invertebrates at Tijuana Estuary.

5. Report Date

May, 31, 1987

6.

7. Author(s)

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8. Performing Organization Rept. No.

9. Performing Organization Name and Address

San Diego State University
San Diego, CA 92182

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

NOAA
Office of Ocean and Coastal Resource Management
Marine and Estuarine Management Division

13. Type of Report & Period Covered

14.

15. Supplementary Notes

Fishes and invertebrates responded differently to the impacts of elevated

16. Abstract (Limit: 200 words)

Fishes and invertebrates responded differently to the impacts of elevated water salinities and temperatures due to the closure of the estuary mouth; sedimentation as the result of dune sand deposition in estuarine channels; and, dredging to remove those sediments. Increased salinities resulted in the mortality of all benthic invertebrates except spionid worms. Four species of fish showed a negative response to salinities greater than 50 ppt. Gillichthys mirabilis, the longjaw mudsucker, populations showed a lag response to salinity with numbers declining in 1986-87. Sedimentation events resulted in the elimination of bivalve species and decreased densities of polychaetes. Dredging to remove sediments resulted in the coincidental removal of all types of benthic invertebrates. Recruitment from an oceanic source is rapid, with small individuals suseptible to further environmental fluctuations.

17. Document Analysis a. Descriptors

Estuaries, fishes, benthic invertebrates, sedimentation, salinity, dredging.

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement | 19. Security Class (This Report) | 21. No. of Pages

20. Security Class (This Page) | 22. Price

(ANSI-Z39.18) | See Instructions on Reverse | OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

NOAA TECHNICAL MEMORANDUM

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TIJUANA RIVER NATIONAL ESTUARINE RESEARCH RESERVE

by

Christopher S. Nordby

31 May 1987

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
OFFICE OF OCEAN AND COASTAL RESOURCE MANAGEMENT
MARINE AND ESTUARINE MANAGEMENT DIVISION
WASHINGTON, D.C.